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**PATENT  
EXPEDITED PROCEDURE ACT  
UNDER 37 C.F.R. §1.116**

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

Applicant(s): Soon-Jai Khang et al.  
Application No.: 09/712,626  
Filed: November 14, 2000  
Title: METHOD AND APPARATUS FOR TREATING FLUE GAS  
Art Unit: 1754  
Examiner: Timothy Vanoy  
Atty Doc. No.: UOC-128D

Cincinnati, Ohio

February 9, 2004

Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

**Declaration of Timothy C. Keener, Ph.D.**

I, Timothy C. Keener, Ph.D., declare as follows:

I am a professor of civil and environmental engineering at the University of Cincinnati ("UC"), in the College of Engineering, Department of Civil and Environmental Engineering, and have served in that capacity since 1982 (assistant professor, 1982-88; associate professor, 1989-92). In addition, I am the director of the UC Environmental Training Institute, a position I have held since 1992. I earned my Ph.D. degree in civil (environmental) engineering from The University of Tennessee ("UT") in 1982, my master of science degree in environmental engineering from UT in 1977, and my bachelor of science degree in mechanical engineering from UT in 1975. For further information regarding my experience and training, please refer to my curriculum vitae, a copy of which is included as a part of this declaration and identified as

"Appendix". I am a co-inventor of the invention described in the above-referenced patent application, and am familiar with the prosecution of the patent application.

2. I understand that the examiner has suggested that Fig. 1 of the above-referenced application is prior art to the invention, reasoning that Fig. 1 bears the title "A Typical 500 MW Power Plant".

3. However, Fig. 1 is not prior art to the invention. Instead, Fig. 1 is a schematic, flow diagram of various aspects of the invention described in the above-referenced patent application.

4. In addition, the caption "A Typical 500 MW Power Plant" which appears at the top of Fig. 1 is a misnomer, as would be appreciated by one of ordinary skill in the art upon skimming Fig. 1. For example, because the aspects of the invention depicted in Fig. 1 are not prior art, Fig. 1 is not "typical". Also, because Fig. 1 does not depict a power plant, the Fig. 1 caption is erroneous. In further detail, one of ordinary skill in the art knows that a power plant includes a fuel (e.g., coal) handling system and a furnace. However, Fig. 1 includes none of these elements. To avoid any confusion, I suggest that the caption be removed from Fig. 1.

I declare that all statements made in this declaration of my own knowledge are true, and that all statements made on information and belief are believed to be true; I further declare that I have made these statements with the knowledge that willful false statements are punishable by fine or imprisonment, or both, under 18 U.S.C. §1001, and that such willful false statements may jeopardize the validity of the application and any patent issued from the application.

  
Timothy C. Keener, Ph.D.

Feb. 9, 2007  
Date

K:\CGC\128D\Declaration of Timothy Keener Ph.D.wpd

## Appendix A

### Timothy Clark Keener, PhD, PE, QEP



**PERSONAL:** Married, 2 children

**ADDRESS:** Department of Civil and Environmental Engineering  
Mail Location #71  
University of Cincinnati  
Cincinnati, Ohio 45221

**CONTACT:** (513) 556-3676 FAX: (513) 556-2599  
e-mail: [Tim.Keener@uc.edu](mailto:Tim.Keener@uc.edu)  
Web site: <http://www.eng.uc.edu/~tkeener>

**CURRENT POSITION:** Professor of Civil and Environmental Engineering  
Director, University of Cincinnati Environmental Training Institute

**EDUCATION:** Vanderbilt University; Pre-engineering program, 1966.  
The University of Tennessee; Mechanical Engineering; B.S. in Mechanical Engineering, 1975.  
The University of Tennessee; Civil Engineering; M.S. in Environmental Engineering, 1977.  
The University of Tennessee; Civil Engineering; Ph.D. in Civil (Environmental) Engineering, 1982.

**EXPERIENCE:**

1982-present	Assistant Professor (1982-88), Associate Professor (1989-92) and Professor of Civil and Environmental Engineering in the Air Pollution Program at the University of Cincinnati. Duties have included teaching, research on a variety of air pollution related areas, student advising and administration of the Air Pollution Program, and the Energy Laboratory, a multi-disciplinary research group involved with issues related to energy production. Have managed over \$6,500,000 of funded research and training activities in the field of air pollution control, air quality management and energy related environmental issues.
1992- present	Director of the University of Cincinnati Environmental Training Institute. Have established and managed UC ETI. The responsibilities of the Environmental Training Institute are to provide intensive short course training to private industry and governmental environmental professionals in air pollution control/air quality management areas.
1987-94	Graduate Studies Director, Civil and Environmental Engineering Department. Managed all graduate studies activities for the Department.

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- 1991 - Visiting Professor at King Mongkut Institute of Technology Thonburi, Bangkok, Thailand. Worked on a variety of air pollution and energy related education programs in Thailand. Duties included teaching, consultation and curriculum development.
- 1986 -present Development of a variety of novel air pollution control devices for the control of acid gases.
- 1985 - Development of a mobile solvent recovery system which resulted in the formation of an Ohio company dealing with waste solvent reclamation.
- 1984 - Visiting Professor at the Energy Research Center, University of North Dakota, working on a project to evaluate pressure hydrated lime for removal of  $\text{SO}_2$ . Project resulted in kinetic data on dehydration of  $\text{Ca}(\text{OH})_2$  and methods of increasing sorbent utilization.
- 1980-1982 Design and operation of a laboratory fixed bed reactor system to evaluate dry sorbents for sulfur dioxide removal from simulated flue gas. This DOE funded research was for a parametric evaluation of different sorbents and determination of the rate limiting steps for the gas-solid reaction.
- 1978-1979 Co-principal investigator on large scale (15,000 acfm, \$1.2 million) demonstration unit evaluation dry FGD system utilizing slaked calcined lime in conjunction with a spray dryer and fabric filter collector. Duties included design, testing and data evaluation for system optimization.
- 1976-1978 Design and operation of a portable pilot plant fabric filter to operate on coal fired boilers. Duties included overseeing the testing and theoretical evaluations of a system for ammonia injection and sodium bicarbonate injection for sulfur dioxide removal from stack gases.
- 1974-1976 Graduate Assistant; Air pollution research for various projects. Job responsibilities: 1974-1975, Testing and evaluating pressure drop characteristics of fabric filters on bench-scale and pilot plant units. Duties included generation of performance curves for different fabrics under varying conditions (dust type, grain loading, face velocity, etc.) 1975; conducted a literature review of gas flow model studies for electrostatic precipitators. Duties included collecting the literature and writing a report to explain why and how model studies should be performed on precipitators.

Feb. 1, 2004

## PROFESSIONAL SOCIETY AFFILIATIONS:

Registered as a Professional Engineer in the State of Ohio; no. E-63893  
Certified as a Qualified Environmental Professional (QEP); no. 04950012  
Member of the Air and Waste Management Association (1975-present)  
Chairman of the University Education Committee (1982-84)  
Chairman of the Training Division (1984-87)  
Vice-Chairman of the Education Council (1987-90)  
Chairman of the Education Council (1990-93)  
Member (*ex officio*) of the Board of Directors (1990-93)  
Chairman of the J. Deane Sensenbaugh Award Committee (1994-95)  
Member of the Planning Committee (1993-96)  
Elected as a Fellow Member, 1996  
Member of Board of Directors (1997-00)  
Member of the East Central Section of A&WMA (1982-present)  
Member of the Board of Directors of the Southwestern Chapter of A&WMA (1989-92)  
Member of the American Chemical Society (1974-present)  
Member of the American Institute of Chemical Engineers and the Environmental Division (1986-present)  
Member of the American Society of Engineering Education (1987-present)

## HONORS & AWARDS:

- American Society of Civil Engineers Year 2001 *Journal of Environmental Engineering* Editor's Award.
- Nominated for the University of Cincinnati's George B. Rieveschl Jr. Award for Scholarly or Creative Works, 2001.
- United States-Asia Environmental Partnership Program (AEP) Environmental Exchange Program Award. From the U.S. Agency for International Development to participate in an Environmental Practices Review Training Course from U.S.-AEP in Singapore on May 22-24, 2000.
- Awarded a gift of \$10,000 from the Procter & Gamble Corporation for contributions in the area of measurement and modeling of volatile organic compound emissions from wastewater treatment plants, 1998.
- Awarded a gift of \$10,000 from the Procter & Gamble Corporation for outstanding service to the environmental engineering profession, 1997.
- *Air & Waste Management Association's* Lyman A. Ripperton Award, 1997.
- Elected as a Fellow Member of the *Air & Waste Management Association*, 1996.
- Elected to the Board of Directors of the *Air & Waste Management Association*, 1996.
- Nominated for the University Of Cincinnati's College of Engineering Research Award (1996)
- Certificate for Outstanding Teaching from the Student Tribunal of the University of Cincinnati College of Engineering (1989)
- Nominated for the University of Pittsburgh Award for Innovation in Coal Conversion (1989)
- Member of the Research Honorary Society of the Sigma Xi since 1983.

## SERVICE:

### Professional Society Related Service:

- Volunteer for the University of Cincinnati Adopt An Applicant ethnic recruitment and retention program, 1996.
- Member of the Board of Trustees of the *Institute of Professional Environmental Practice* (1993-95)
- Member of the Steering Committee and Chairman of the Student Program for the 87<sup>th</sup> Annual Meeting of the Air & Waste Management Association, 1994.
- Have served as Chair and Co-Chair for various technical sessions and meetings of the American Chemical Society, Air Pollution Control Association, Pittsburgh Coal Conference, World Congress III on Engineering and Environment.
- Serve as Faculty Advisor to Chi Epsilon Chapter at UC (1986-93) and to the UC Student Chapter of the Air and Waste Management Association (1984-present)

### Technical Service:

- Technical Editor-in-Chief, *Journal of the Air & Waste Management Association*, June 2003 - present.
- Proposal reviewer for the U.S. Civilian Research and Development Foundation (CRDF), 2000
- Member of the Editorial Committee of the *Journal of the Archives of Environmental Protection*, published by the Institute of Environmental Engineering of the Polish Academy of Sciences, 2000-2004.
- Member of the U.S. EPA peer review panel for Small Business Innovation Research (SBIR) Phase I: Air Panel, Washington, D.C., February 8-9, 2000.
- Book Review Editor for *Environmental Engineering and Policy*, 1998-present.
- Organized and chaired the workshop on *Applications of Electrostatics for Control of Gas Phase Air Pollutants*, University of Cincinnati Civil & Environmental Engineering Department, August 22, 1997, Cincinnati, Ohio
- Member, Editorial Advisory Board of *Advances in Environmental Research*, 1996-present.
- Member of the U.S. Department of Energy peer review panel for Small Business Innovation Research (SBIR) Program, 1994.
- Reviewer for: *Advances in Environmental Research, AIChE Journal, ASCE Journal of Environmental Engineering, ASTM, Biotechnology Progress, Chemical Engineering Communications, Chemical Engineering Science, Energy & Fuels, Environmental Engineering and Policy, Environmental Pollution, Fuel, Fuel Processing Technology, Hazardous Waste and Hazardous Materials, Industrial & Engineering Chemistry Research, Journal of Chemical and Engineering Data, and Journal of the Air and Waste Management Association.*
- Member of the National Science Foundation peer review panel for Small Business Innovation Program, 1991.
- Member of the DOE program peer review panel for Combustion: Environmental Developments, Pittsburgh, PA, July, 1990.
- Chairman of the DOE program peer review panel for SO<sub>2</sub> and NO<sub>x</sub> Control Technologies,

Washington, D.C., Aug., 1989.

- Program peer review member for the Illinois Center for Research on Sulfur in Coal, 1988.

#### Academic Service:

- Elected to the Dean's Advisory Committee (2000-2003).
- Civil & Environmental Engineering Department coordinator for the ACCEND Program (2003-present).
- Elected to the College of Engineering Reappointment, Promotion and Tenure Committee (2003-2006).

#### CONSULTING:

Have served as a technical consultant to the following companies and organizations; American National Can, Marion, Indiana; Babcock & Wilcox Co., Alliance, OH; Camargo Associates, Cincinnati, OH; Environair, Quebec, Canada; Flakt Environmental Systems, Knoxville, TN; Hamilton Plastics, Mason, OH; Mel Chemicals, Manchester, England; Pristine, Inc., Cincinnati, OH; US-EPA, RTP, NC; US-DOE, Washington, DC.

Have served as a technical expert for the law firms of Hoeffner, Bilek and Eidman, Houston, TX., Keating, Muething, & Klekamp, P.L.L., Cincinnati, OH., and Ziegler & Schneider, P.S.C., Covington, Kentucky. Have testified before the Environmental Review Appeals Commission, State of Ohio, in the matter of Case No. ERAC 315205 for the University of Cincinnati (October 15, 2003).

#### RESEARCH INTERESTS:

- Research and development of air pollution control processes including particulate control and gaseous pollutant control.
- Development of ammonia enhanced spray drying for control of SO<sub>2</sub> and NO<sub>x</sub> from flue gases (*U.S. Patent No. 5,017,349*).
- Development of the Circulating Fluidized Bed Absorber (CFBA) for control of SO<sub>2</sub> and NO<sub>x</sub> from flue gases.
- Development of mild pyrolysis (thermolysis) for the pretreatment of fossil fuels to reduce emissions of sulfur oxides, nitrogen oxides and mercury.
- Development of a novel coal feeder for production of low sulfur fuel (*U.S. Patent No. 5,037,450*).
- Modeling of vapor phase activated carbon control of volatile organic compounds.
- Modeling and experimental investigations concerning non-catalytic gas-solid reactions with respect to control of acid gases.
- The role of ammonia in the control of acid gases and heavy metals from flue gases.
- The fate and control of VOCs in wastewater treatment plants.
- The control of odors from wastewater treatment plants.

#### FUNDED GRANTS AND CONTRACTS:

"Measurements and Control of Diesel Emissions in Underground Mines," National Institute of



Occupational Health and Safety, September 1, 2002 through August 31, 2005 (Amount awarded \$427,200; Co-Principal Investigator, Dr. Tim C. Keener)

"Reduction of VOC Emissions from Aeration Basins by Recirculating Air: Year 2," Metropolitan Sewer District of Hamilton County, June 18, 2002 - December 31, 2003. (Amount awarded \$49,969; Principal Investigator, Dr. Tim C. Keener).

"Air Pollution Control Training Program," U.S. Environmental Protection Agency; September 1, 2002 through August 31, 2007 (Amount awarded \$234,449; Principal Investigator, Dr. Tim C. Keener)

"Cost-Effective Sorbents for Flue Gas Cleaning," National Research Council, 3/28/02 - 2/29/04, (Amount awarded \$14,600; Principal Investigator, Dr. Tim C. Keener)

"Air Pollution Training at the University of Cincinnati Environmental Training Institute." U.S. Environmental Protection Agency; Year 3 of 3, 10/01/01 - 9/31/02. (Amount awarded \$46,000; Principal Investigator, Dr. Tim C. Keener)

"Mercury Removal from Flue Gas by In-Situ Aerosol Sorbent." The Ohio Coal Development Office, 9/1/01 - 9/30/02. (Amount awarded \$60,000; Co-Principal Investigator, Dr. Tim C. Keener).

"CO<sub>2</sub> Separation and Sequestration Utilizing FGD Scrubber By-Products: Year 2." The Ohio Coal Development Office, 9/1/01 - 9/30/02. (Amount awarded \$79,231; Principal Investigator, Dr. Tim C. Keener).

"Study of Trona (Sodium Sesquicarbonate) Reactivity with Sulfur Dioxide in a Simulated Flue Gas." Solvay Minerals, Inc., 6/01/01 - 1/31/02. (Amount awarded \$36,648; Principal Investigator, Dr. Tim C. Keener).

"Reduction of VOC Emissions from Aeration Basins by Recirculating Air." Metropolitan Sewer District of Hamilton County, 6/01/01 - 12/31/01. (Amount awarded \$33,000; Principal Investigator, Dr. Tim C. Keener).

"Air Pollution Training at the University of Cincinnati Environmental Training Institute." U.S. Environmental Protection Agency; Year 2 of 3, 10/01/00 - 9/31/01. (Amount awarded \$46,000; Principal Investigator, Dr. Tim C. Keener)

"Removal of Mercury From Combustion Flue Gas By The Action of Ammonia-Sulfur Aerosols." The U.S. Environmental Protection Agency, 9/1/00 - 7/30/01. (Amount awarded \$25,000; Co-Principal Investigator, Dr. Tim C. Keener).

"CO<sub>2</sub> Separation and Sequestration Utilizing FGD Scrubber By-Products: Year 1." The Ohio Coal Development Office, 9/1/00 - 9/30/01. (Amount awarded \$76,103; Principal Investigator, Dr. Tim

C. Keener).

"Air Pollution Training at the University of Cincinnati Environmental Training Institute." U.S. Environmental Protection Agency; Year 1 of 3, 10/01/99 - 9/31/00. (Amount awarded \$174,676; Principal Investigator, Dr. Tim C. Keener)

"Drop-Tube Reactor Study of Chemical and Physical Properties of Ohio Coals: Year 4." The Ohio Coal Development Office, 9/1/99 - 8/31/00. (Amount awarded \$75,000; Principal Investigator, Dr. Tim C. Keener).

"An Innovative Method of Scrubbing CO<sub>2</sub> From Flue Gas By Utilizing Wet FGD Scrubber By-Products and Turbine Waste Heat," Cinergy Corporation, as part of their Cinergy - Earth Day - Environmental Research and Development Grants, 4/1/99 - 10/31/2000. (Amount awarded \$15,600; Principal Investigator, Dr. Tim C. Keener)

"Development of a Wet Electrostatic Precipitator for Control of Acid Gases and Trace Metal Emissions: Year 3." The Ohio Coal Development Office, 9/1/98 - 8/31/99. (Amount awarded \$75,000; Co-Principal Investigator, Dr. Tim C. Keener).

"Drop-Tube Reactor Study of Chemical and Physical Properties of Ohio Coals: Year 3." The Ohio Coal Development Office, 9/1/98 - 8/31/99. (Amount awarded \$75,000; Principal Investigator, Dr. Tim C. Keener).

"Air Pollution Training at the University of Cincinnati Environmental Training Institute." U.S. Environmental Protection Agency; Year 1 of 3, September, 1998. (Amount awarded \$167,676; Principal Investigator, Dr. Tim C. Keener)

"Air Pollution Training at the University of Cincinnati Environmental Training Institute." U.S. Environmental Protection Agency; Year 3 of 3, September, 1997. (Amount awarded \$158,650; Principal Investigator, Dr. Tim C. Keener)

"Drop-Tube Reactor Study of Chemical and Physical Properties of Ohio Coals: Year 2." The Ohio Coal Development Office, 9/1/97 - 8/31/98. (Amount awarded \$75,000; Principal Investigator, Dr. Tim C. Keener).

"Development of a Wet Electrostatic Precipitator for Control of Acid Gases and Trace Metal Emissions: Year 2." The Ohio Coal Development Office, 9/1/97 - 8/31/98. (Amount awarded \$75,000; Co-Principal Investigator, Dr. Tim C. Keener).

"Use of Reclaimed Magnesium Hydroxide as a Wastewater Treatment Reagent." 10/1/97-9/30/00; The Ohio Coal Development Office, \$275,575; CINERGY Corporation, \$70,421; Dravo Lime Company, \$48,670. (Co-Principal Investigator, Dr. Tim C. Keener)

"Evaluating the Performance of the New Biofilters at the Mill Creek Wastewater Treatment Plant."

The Hamilton County Metropolitan Sewer District, 10/1/97-9/30/98; \$40,000. (Co-Principal Investigator, Dr. Tim C. Keener)

"Air Pollution Training at the University of Cincinnati Environmental Training Institute." U.S. Environmental Protection Agency; Year 2 of 3, September, 1996. (Amount awarded \$150,148; Principal Investigator, Dr. Tim C. Keener)

"Fundamental Study of Chemical and Physical Properties of Ohio Coals that Affect Pollutant Emissions from PC Boilers: Year 1." The Ohio Coal Development Office, 9/1/96 - 8/31/97. (Amount awarded \$112,250; Principal Investigator, Dr. Tim C. Keener).

"Medium/Low Temperature Emission Control: Development of a Wet Electrostatic Precipitator for Control of Acid Gases and Trace Metal Emissions." The Ohio Coal Development Office, 9/1/96 - 8/31/97. (Amount awarded \$94,990; Co-Principal Investigator, Dr. Tim C. Keener).

"Determination of the  $\text{Ca}(\text{OH})_2$  Dissolution Rate For Enhancement of Spray Dryer Performance of  $\text{SO}_2$  Control." The Ohio Coal Development Office, 9/1/94 - 8/31/95. (Amount awarded \$70,000; Principal Investigator, Dr. Tim C. Keener).

"Air Pollution Training at the University of Cincinnati Environmental Training Institute." U.S. Environmental Protection Agency; Year 1 of 3, September, 1995. (Amount awarded \$150,056; Principal Investigator, Dr. Tim C. Keener)

"Evaluation of Portland Cement Slurries in a Spray Dryer Reactor for Control of Sulfur Dioxide." The Ohio Coal Development Office, 9/1/94 - 8/31/95. (Amount awarded \$65,532; Principal Investigator, Dr. Tim C. Keener)

"Air Pollution Training at the University of Cincinnati Environmental Training Institute." U.S. Environmental Protection Agency, September, 1994. (Amount awarded \$240,000; Principal Investigator, Dr. Tim C. Keener)

"A Study to Investigate the Interaction Between Sodium Bicarbonate, NO and  $\text{SO}_2$ ." The Electric Power Research Institute, April, 1994. (Amount awarded \$90,965; Principal Investigator, Dr. Tim C. Keener)

"Production of Elemental Sulfur From  $\text{H}_2\text{S}$  and  $\text{CO}_2$  Derived From a Coal Desulfurization Process." The U.S. Department of Energy, September, 1993-1995. (Amount awarded \$199,998; Co-Principal Investigator, Dr. Tim C. Keener).

"The Effects of Additives on Lime and Limestone Dissolution Rates for Enhancement of Spray Dryer Performance on  $\text{SO}_2$ ." The Ohio Coal Development Office, September, 1993. (Amount awarded \$66,574; Principal Investigator, Dr. Tim C. Keener).

"Properties of Calcium Silicate/Calcium Aluminate Sorbents Formed from Heated Fly

Ash/Hydrated Lime Slurries." The Ohio Coal Development Office, September, 1993. (Amount awarded \$49,836; Principal Investigator, Dr. Tim C. Keener)

"Air Pollution Training at the University of Cincinnati Environmental Training Institute." U.S. Environmental Protection Agency, September, 1993. (Amount awarded \$299,999; Principal Investigator, Dr. Tim C. Keener)

"Air Pollution Training at the University of Cincinnati Environmental Training Institute." U.S. Environmental Protection Agency, September, 1992. (Amount awarded \$368,131; Principal Investigator, Dr. Tim C. Keener)

"Graduate Assistance in Hazardous Waste Management: Hazardous Waste Fellowship Program 1992-1993." U.S. Department of Education, September, 1992 (Amount awarded \$204,355; Principal Investigator, Dr. Tim C. Keener)

"Production of Elemental Sulfur From Spent Sorbent and CO<sub>2</sub>," The Ohio Coal Development Office, January, 1992 (Amount awarded \$64,940; Principal Investigator, Dr. Tim C. Keener).

"Graduate Assistance in Hazardous Waste Management: Hazardous Waste Fellowship Program 1991-1992." U.S. Department of Education, September, 1991 (Amount awarded \$194,765; Principal Investigator, Dr. Tim C. Keener)

"Kinetic Studies, Thermal Decomposition and Effects of Humidity and Additives on SO<sub>2</sub> Removal," The Ohio Coal Development Office, Sept., 1991. Year 2 Funding from the Consortium of Ohio Universities (Amount awarded \$118,723; Co-Principal Investigator, Dr. Tim C. Keener).

"Sorbent Utilization Studies Using a Mini-Pilot Spray Dryer," The Ohio Coal Development Office, Sept., 1991. Year 2 Funding from the Consortium of Ohio Universities (Amount awarded \$66,403; Principal Investigator, Dr. Tim C. Keener).

"Effect of Sorbent Attrition on Utilization," The Ohio Coal Development Office, Sept., 1991. Year 2 Funding from the Consortium of Ohio Universities (Amount awarded \$60,425; Principal Investigator, Dr. Tim C. Keener).

"Low Temperature SO<sub>2</sub> Control in a Circulating Fluidized Bed Absorber," The U.S. Department of Energy, October, 1991. (Amount awarded \$26,051; Principal Investigator, Dr. Tim C. Keener)

"Sorbent Utilization Studies Using a Mini-Pilot Spray Dryer," The Ohio Coal Development Office, June, 1990. Year 1 Funding from the Consortium of Ohio Universities (Amount awarded \$49,119; Principal Investigator, Dr. Tim C. Keener).

"Effect of Sorbent Attrition on Utilization," The Ohio Coal Development Office, June, 1990. Year 1 Funding from the Consortium of Ohio Universities (Amount awarded \$67,688; Principal Investigator, Dr. Tim C. Keener).

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"Kinetic Studies, Thermal Decomposition and Effects of Humidity and Additives on SO<sub>2</sub> Removal," The Ohio Coal Development Office, June, 1990. Year 1 Funding from the Consortium of Ohio Universities (Amount awarded \$124,655; Co-Principal Investigator, Dr. Tim C. Keener).

"Air Pollution Training Program," The U.S. Environmental Protection Agency, June, 1989. (Amount awarded \$165,228; Principal Investigator, Dr. Tim C. Keener).

"A Study of the NH<sub>3</sub>-SO<sub>2</sub> Reaction in the Presence of Aerosols," The Ohio Coal Development Office, March, 1989. (Project amount \$134,815; Principal Investigator, Dr. Tim C. Keener)

"Chemical Fixation of Flue Gas Desulfurization Sludges and Flyash," The Ohio Coal Development Office, March, 1989. (Project amount \$227,053; Co-Principal Investigator, Dr. Tim C. Keener)

"Ammonia Regeneration For a Combined Lime/Ammonia Spray Dryer System for Control of SO<sub>2</sub>," The Ohio Coal Development Office, March, 1989. (Project amount \$171,938; Principal Investigator, Dr. Tim C. Keener)

"A Novel Coal Feeder For Production of Low Sulfur Fuel," The U.S. Department of Energy, January, 1989. (Amount awarded \$198,419; Co-Principal Investigator, Dr. Tim C. Keener)

"A Proposal to Investigate the Development of a Novel Coal Feeder System," The Ohio Coal Development Office, January, 1989. (Project amount \$149,565; Principal Investigator, Dr. Tim C. Keener).

"Demonstration of a Ca(OH)<sub>2</sub>/NH<sub>3</sub> Based System for Removal of SO<sub>2</sub> on High Sulfur Coals," The Ohio Coal Development Office, Columbus, Ohio, 1986. (Project amount \$143,000; Principal Investigator, Dr. Tim C. Keener)

"The Use of a Circulating Fluidized Bed Absorber for Control of SO<sub>2</sub> Emissions," The Ohio Coal Development Office, Columbus, Ohio, 1986. (Project amount \$175,000; Principal Investigator, Dr. Tim C. Keener)

"Removal of SO<sub>2</sub> Via a Porous Membrane Media," The Herman Schneider Laboratory, University of Cincinnati, November, 1985. (Amount awarded \$3,500; Principal Investigator, Dr. Tim C. Keener)

"Development of a Mobile Solvent Recovery System for Hazardous Waste Treatment," The Thomas Alva Edison Partnership Program, Columbus, Ohio, July, 1985. (Project amount \$345,964; Principal Investigator, Dr. Tim C. Keener)

"Air Pollution Training Renewal," The U.S. Environmental Protection Agency, Washington, D.C., May, 1985. (Amount awarded \$51,000; Principal Investigator, Dr. Tim C. Keener)

"Pilot Scale Evaluation of Carbon Adsorption for Removal of Oxidant Precursors - Phase II, Matrix

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Testing," The U.S. Environmental Protection Agency, Cincinnati, Ohio, July, 1984. (Amount awarded \$50,000; Principal Investigator, Dr. Tim C. Keener)

"Air Pollution Training," The U.S. Environmental Protection Agency, Washington, D.C., May, 1984. (Amount awarded \$38,000; Principal Investigator, Dr. Tim C. Keener)

"Pilot Scale Evaluation of Carbon Adsorption for Removal of Oxidant Precursors - Phase 1, Development of a Test Plant," The U.S. Environmental Protection Agency, Cincinnati, Ohio, February, 1984. (Amount awarded \$20,000; Principal Investigator, Dr. Tim C. Keener)

"Acquisition of a Sulfur Dioxide Monitor," The Herman Schneider Laboratory, The University of Cincinnati, October, 1983. (Amount awarded \$3,500; Principal Investigator, Dr. Tim C. Keener)

"Microcomputers for Air Pollution Control Engineering," The University Research Council, The University of Cincinnati, April, 1983. (Amount awarded \$2,500; co-authors William Licht and M.R. Ruby.)

"Installation of a Pilot Scale Fabric Filter Collector," The University Research Council, The University of Cincinnati, April, 1983. (Amount awarded \$500.)

#### SHORT COURSES DIRECTED:

***"Environmental Practices Review Course,"***

Prepared and conducted for The Air & Waste Management Association;

Given ~2 times per year at various locations around the United States.

***Founder and Director of the University of Cincinnati Environmental Training Institute. Since 1984, UC ETI has presented approximately 6 short courses annually on topics dealing with Air Pollution Control/Air Quality Management issues both nationally and internationally.***

#### LIST OF COURSES

***Source Sampling for Particulate Pollutants***

***Control of Particulate Emissions***

***Combustion Evaluation***

***Continuous Emission Monitoring***

***Control of Gaseous Emissions***

***Principles of Hazardous Waste Incineration***

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**THESES AND DISSERTATIONS DIRECTED:****PhD Students**

9. "The Production of NO<sub>2</sub> from the Injection of Sodium Bicarbonate to Control SO<sub>2</sub> in Combustion Flue Gases," Antoinette Stein, Ph.D. Dissertation, The University of Cincinnati, August, 2001.
8. "Enhanced Pulsed Corona Method for Removal of SO<sub>2</sub> and NO<sub>x</sub> from Combustion Flue Gas in a Wet Electrostatic Precipitator," Chao-Heng Tseng, Ph.D. Dissertation, The University of Cincinnati, June, 2000.
7. "Removal of Sulfur Dioxide in Baghouses Following Convective Pass Sorbent Injection," Guang Li, Ph.D. Dissertation, The University of Cincinnati, June 1997.
6. "Advances in Spray Drying Desulfurization for High Sulfur Coals," Jun Wang, Ph.D. Dissertation, The University of Cincinnati, December, 1996.
5. "Studies of Chemical Reduction of Fe(III)\*EDTA in an NO<sub>x</sub>/SO<sub>2</sub> Aqueous Scrubber System," Wen Li, Ph.D. Dissertation, The University of Cincinnati, June, 1994.
4. "Attrition and Low Temperature Sulfur Dioxide Removal by Dry Lime (CaO) in a Circulating Fluidized Bed Absorber (CFBA)," Sang-Kwun Lee, Ph.D. Dissertation, The University of Cincinnati, June, 1993.
3. "The Pore Structure of Porous Calcium Oxide from Calcium Carbonate During Thermal Decomposition," Jia-Twu Lee, Ph.D. Dissertation, The University of Cincinnati, February, 1992.
2. "Fundamental Study of Ammonia-Sulfur Dioxide Reactions to Form Solid Particles," Hsunling Bai, Ph.D. Dissertation, The University of Cincinnati, January, 1992 (Co-advisor).
1. "The Role of Humidification and Attrition on Sulfur Dioxide Removal in a Circulating Fluidized Bed Absorber," Xiaolin Jiang, Ph.D. Dissertation, The University of Cincinnati, January 1991.

**Masters Students**

43. "Reclamation of Reclaimed Asphalt Pavement (RAP) by Pyrolysis," Pradnya Kulkarni, Master's Thesis, The University of Cincinnati, August, 2003.
42. "Examination of the Ammonia-Sulfur Dioxide Water System Using FTIR Spectroscopy," Laura Spriggs, Master's Thesis, The University of Cincinnati, June, 2002.
41. "A Study of NO<sub>x</sub> Emissions as Affected by the Chemical and Physical Properties of Ohio Coals in a Drop Tube Reactor," Kyung Sook Jung, Master's Thesis, The University of Cincinnati, March, 2001.

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40. "A Technical and Economic Comparison of Biofilters and Wet Chemical Scrubbers for Odor Control at Wastewater Treatment Plants." Li Gao, Master's Thesis, The University of Cincinnati, August, 2000.
39. "Evaluation of Biofilter Odor Reduction Potential in Wastewater Treatment Plants," LiAn Zhuang, Master's Thesis, The University of Cincinnati, June, 2000.
38. "Mechanisms of Gaseous Pollutant Formation During the Combustion of Ohio Coals," Ming Zhou, Master's Thesis, The University of Cincinnati, August, 1999.
37. "Study of Sodium Sulfite in Gaseous NOx Removal," Kasemsan Manomaiphiboon, Master's Thesis, The University of Cincinnati, June, 1999.
36. "Experimental Study of Hydration of Solid Calcium Oxide Sorbent: Application in the circulating Fluidized Bed Absorber (CFBA)," Dhiraj Solomon, Master's Thesis, The University of Cincinnati, March 1999.
35. "Entrained Flow Drop-Tube Reactor for the Study of Combustion of Ohio Coals," Fang Liu, Master's Thesis, The University of Cincinnati, December 1998.
34. "Emissions of Volatile Organic Compounds from Publicly Owned Treatment Works and Emission Reductions Using Circulating Aeration," Hongwei Zhu, Master's Thesis, The University of Cincinnati, August 1998.
33. "Investigation of Mercury Removal from Low Volatility Bituminous Coal During Mild Pyrolysis," Min Wang, Master's Thesis, The University of Cincinnati, March 1998.
32. "Fate of Chlorine, Carbon and Hydrogen from the Pyrolysis of Polyvinyl Chloride (PVC)," John W. Weber, Master's Thesis, The University of Cincinnati, December 1997.
31. "Enhanced Electrostatic Precipitation for the Removal of Sulfur Dioxide," Karen Larkin, Master's Thesis, The University of Cincinnati, June 1997.
30. "A Novel Analytical Method for Determining Volatile Organic Compounds in the Air of an Industrial Setting Using Tedlar® Sample Bags," Timothy Orton, Master's Thesis, The University of Cincinnati, June 1997.
29. "Evaluation of Precombustion Control of Mercury Emissions by Mild Pyrolysis in a Rijke Pulse Combustor," Andrew Wolf, Master's Thesis, The University of Cincinnati, June 1997.
28. "Investigation into the Fate of Trace Mercury in Coal During Mild Pyrolysis," Amy Merdes, Master's Thesis, The University of Cincinnati, March 1997.
27. "Characterization of Air Emissions from a Microwave Plasma Deposition Process," Daniel Anderson, Master's Thesis, The University of Cincinnati, December, 1996.

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26. "Evaluation of Hydrated Cement Sorbents for Flue Gas Desulfurization in a Pilot Spray Dryer," Gene Meyers, Master's Thesis, The University of Cincinnati, December, 1996.
25. Gururaj Mysore, Master's Project, The University of Cincinnati, August, 1996.
24. "Effectiveness of Methyl Methacrylate Adsorption onto Activated Carbon Under conditions of Varying Humidity," Juliette E. Fero, Master's Thesis, The University of Cincinnati, August, 1995.
23. "Production of Elemental Sulfur From Spent Sorbent and CO<sub>2</sub>," Deborah Ann Soriano, Master's Thesis, The University of Cincinnati, August, 1994.
22. "Surface Area Changes Due to Carbonation and Sulfation of Calcium Hydroxide and Dolomite in the Medium Temperature Range for Flue Gas Desulfurization Operation," Prakash G. Menon, Master's Thesis, The University of Cincinnati, August, 1994.
21. "Fate of Chlorine in Coal Under Mild Pyrolysis," Zhiyin Zu, Master's Thesis, The University of Cincinnati, June, 1994.
20. "An Estimate of Particulate Effects on Total Suspended Particulate Matter Concentrations at Nine Monitoring Sites in Hamilton County, Ohio From 1975 - 1984," John F. Funke, Master's Thesis, The University of Cincinnati, December, 1993.
19. "Performance Evaluation of Three Carbon Monoxide Urban Intersection Air Quality Dispersion Models in the Indianapolis Area, Mark B. Caraher, Master's Thesis, The University of Cincinnati, December, 1992.
18. "A Study of the Potential of Stabilizing Waste Volatile Organic Materials with Flue Gas Desulfurization Waste Solids, Chong-Le Li, Master's Thesis, The University of Cincinnati, August, 1992.
17. "Analysis of Radiation Levels in Air Monitoring Data From the Savannah River Project," Mark A.R. Knoderer, Master's Thesis, The University of Cincinnati, June, 1992.
16. "Operational Comparison of Three Complex Terrain Dispersion Models Under Unstable Stability Conditions," Chang-Gai Lee, Master's Project, The University of Cincinnati, August, 1992.
15. "Economic Analysis and Comparison of the Circulating Fluidized Bed Absorber (CFBA) FGD Process," Paul D. Pan, Master's Thesis, The University of Cincinnati, March, 1992.
14. "Coal Denitrification by Mild Pyrolysis," Thih-Liang Yeh, Master's Thesis, The University Of Cincinnati, August, 1991.
13. "A Further Evaluation of CO Intersection Model Techniques- An Application of the Bootstrap Resample Method," Shih- Wei Tsou, Master's Thesis, The University of Cincinnati, August,

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1991.

12. "Modeling of the Mixed Flow Spray Dryer," Qing Yang, Master's Thesis, The University of Cincinnati, August, 1991.
11. "Experimental Study of a Novel Coal Feed System for the Production of Low Sulfur Fuel," Xiaolu Yu, Master's Thesis, The University of Cincinnati, June, 1991.
10. "Ammonia Regeneration for a Combined Lime/Ammonia Spray Dryer Process," Xinjian Yang, Master's Thesis, The University of Cincinnati, Feb. 1991.
9. "Effects of Relative Humidity on Multi Component Vapor Adsorption of Toluene and Methylene Chloride by Activated Carbon," Runzhi Gong, Master's Thesis, The University of Cincinnati, November, 1989.
8. "Reaction Kinetics of Quicklime and Hydrogen Chloride in a Simulated Flue Gas at High Temperatures," Kevin P. Batt, Master's Thesis, The University of Cincinnati, June, 1989.
7. "An Operational Comparison of Three Complex Terrain Dispersion Models," Jayant A. Hardikar, Master's Thesis, The University of Cincinnati, June, 1989.
6. "Characterization of Waste Products From an Enhanced Lime/Ammonia Spray Dryer Flue Gas Desulfurization System," Jia-Twu Lee, Master's Thesis, The University of Cincinnati, June, 1989.
5. "Activated Carbon Performance Under High Humidity Conditions," Derong Zhou, Master's Thesis, The University of Cincinnati, March, 1988.
4. "Control of Kraft Mill Lime Kiln Total Reduced Sulfur Emissions," David M. Bryer, Master's Thesis, The University of Cincinnati, June, 1988.
3. "Comparison of Actual Versus Predicted HCl Concentrations in a Pilot Liquid Incinerator," Randall L. Abbuhl, Master's Thesis, The University of Cincinnati, August, 1988.
2. "A Study in the Change of Surface Area of Limestone Due to Thermal Decomposition," Xiaolin Jiang, Master's Thesis, The University of Cincinnati, December, 1986.
1. "The Removal of Sulfur Dioxide from Coal-Fired Boiler Flue Gas by Ammonia Injection," Martin J. Stromberger, Master's Thesis, The University of Cincinnati, December, 1984.

#### STUDENT ADVISEE'S AWARDS

**Laura Spriggs:** 2001 National Scholarship award from the Air & Waste Management Association for Masters students.

**Ming Zhou:** 1999 Scholarship (\$1,000) from the Air & Waste Management Association, East Central

## Section.

**Gunag Li:** Best Paper at the International Conference on Environmental Protection of Electric Power, Nanjing, China, 1996 ("Extended study on the Potential of Baghouses in Enhancing SO<sub>2</sub> Removal Following Convective Pass Sorbent Injection")

**Hongwei Zhu:** First-Place Award from Ohio Water Environment Association Student Paper Competition, 1996 ("Spatial Variation of VOC Emissions from Aeration Tanks").

**Wen Li:** Second Place Award, PhD Category, Air & Waste Management Association Annual Meeting Student Paper Competition, 1993 ("Studies of Chemical Reduction of Fe(III)\*EDTA in an NO<sub>x</sub>/SO<sub>2</sub> Aqueous Scrubber System").

**Xiaolin Jiang:** First Place Award, PhD Category, Air & Waste Management Association Annual Meeting Student Paper Competition, 1989 ("The Use of a Circulating Fluidized Bed Absorber to Control SO<sub>2</sub>").

## COURSES TAUGHT AND DEVELOPED:

### 20-257-271 Environmental Engineering I

Introductory course covering the following topics; overview of environmental legislation; hydrology; water treatment; water quality management; wastewater treatment; and, air pollution.

### 20-257-342 Environmental Engineering II

Fundamental concepts of environmental engineering analysis: stoichiometry, kinetics and material balances; reactor design; mathematical models for transport of contaminants. Introduction to Air Pollution Control/Air Quality Management and Solid Waste Management.

### 20-257-345 Environmental Material Balances

Developed 20-257-345 "Environmental Material Balances." Introduction to techniques for the analysis of environmental systems. Applications of concepts of material and energy balances to environmental systems as part of the engineering approach to problem solving.

### 20-257-392 Fluid Mechanics

Properties of fluids; fluid statics; kinematics of fluid flow; energy considerations in steady flow; basic hydrodynamics; and, momentum and forces in fluid flow.

### 20-257-427 Mathematical Simulation of Engineering Systems

Computer applications in civil engineering; introduction to problem solving; problem solving and algorithms; design of algorithms; efficiency of algorithms; characteristics of mathematical functions; locating zeros and root finding; deterministic simulation; and, probabilistic simulation.

### 20-257-661 Introduction to Air Pollution Control

Effects and sources of air pollutants; federal legislation and regulatory trends; meteorology; dispersion of pollutants in the atmosphere; atmospheric photochemical reactions; control of

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particulates; control of gases and vapors; and, mobile sources.

#### 20-257-664 Air Quality Management

Objectives are to familiarize students to general aspect of air pollution control and management. Topics include general knowledge of laws and regulations governing the management and control of air pollution in the United States, meteorological impacts on dispersion and transformation of air pollutants and basic principles of control technologies, both for particulate and gaseous air pollutants.

#### 20-257-669 Industrial Sources Air Pollution

Developed course 20-257-669, "Industrial Sources of Air Pollution." This course has required showing students operating industrial sources of air pollution and reviewing the technical and regulatory requirements for air pollution abatement. The in-class lectures are strengthened with field trips to industrial sources for tours.

#### 20-257-673 Diffusion and Mass Transfer in Environmental Systems

Developed course 20-257-673, "Diffusion and Mass Transfer in Environmental Systems." This advanced level course was developed to enhance the ability of environmental students to analyze environmental systems in terms of diffusion and mass transfer. Objectives include to study the fundamentals of diffusion and mass transfer as related to the control of environmental pollutants. Topics covered include analysis of diffusion and mass transfer problems, diffusion in dilute and concentrated solutions, dispersion, mass transfer, determination of mass transfer coefficients, forced convection and gas/solid reactions.

#### 20-257-674 Design of Gaseous Pollutant Control Devices

This advanced level course was developed and designed to familiarize the student with techniques for controlling gaseous air pollutants. The basic principles of adsorption, absorption, incineration, as well as duct design and fan selection, and the measurement of gas pollutants are covered. In addition, the course includes discussions concerning data required for the design of flue gas desulfurization and denitrification systems.

#### 20-257-766 Air Pollution Control Laboratory

Developed this gas cleaning laboratory course (20-257-766) in conjunction with course 20-257-674, "Control of Gaseous Pollutants." This involved designing and constructing a mini-liquid gas scrubber capable of illustrating how mass transfer coefficients are obtained by experiments. The data acquisition for this unit is by microcomputers, and helps acquaint the student with modern data acquisition systems.

**Introduced microcomputers into courses.** Dr. Keener has consistently been one of the first to introduce students to the advantages of microcomputers. He had the second IBM-PC in the College of Engineering in January, 1983. He required all reports in the Air Pollution Program to be by word processors in 1984, developed a PC based data acquisition laboratory in 1986, and introduced PC's to undergraduate environmental engineering students in 20-257-271 in 1987.

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## PUBLICATIONS

*Refereed Journal Publications*

"Mercury Removal from Flue Gas with Aerosols Generated by  $\text{SO}_3\text{-NH}_3$  Reactions," Joo-Youp Lee, Soon-Jai Khang and Tim C. Keener, *Industrial & Engineering Chemistry Research*, in review, 2003.

" $\text{CO}_2$  Absorption Study in a Bubble Column Reactor with  $\text{Mg}(\text{OH})_2$  Slurries," Kyung Sook Jung, Tim. C. Keener, Victoria Green and Soon-Jai Khang, *International Journal of Environment and Pollution*, in press.

"A Technical and Economic Evaluation of  $\text{CO}_2$  Separation from Power Plant Flue Gases with Reclaimed  $\text{Mg}(\text{OH})_2$ ," Kyung-Sook Jung, Tim C. Keener, Soon-Jai Khang and Sang-Kwun Lee, *Clean Technologies and Environmental Policy*, in press.

"A Model for Dry Sodium Bicarbonate Duct Injection Flue Gas Desulfurization," Changfa Wu, Soon-Jai Khang and Tim C. Keener, *Advances in Environmental Research*, 8, pg 655-666, 2004.

"The Effects of Pulsed Corona Discharge on  $\text{SO}_2$  Absorption into Water from  $\text{SO}_2$ /Air Mixture, Joo-Youp Lee, Soon-Jai Khang, and Tim C. Keener, *Industrial & Engineering Chemistry Research*, 42, 2030-2032, 2003.

"Biological Phosphate Uptake and Release: Effect of pH and  $\text{Mg}^{2+}$ ," Qingzhong Wu, Paul L. Bishop and Tim C. Keener, submitted to *Water Environment Research*, July, 2002.

"A New Strategy to Reduce the Risk of Struvite Deposition in Municipal; Wastewater Treatment Plants," Qingzhong Wu, Paul L. Bishop and Tim C. Keener, *Water Environment Research*, in press.

"Formation and Biodegradation of Toluene in The Anaerobic Sludge Digestion Process," Bozena Mrowiec, Jan Suschka and Tim C. Keener, accepted for publication in *Water Environment Research*, March, 2002.

"The Pyrolysis Behavior of Mixtures of Commodity Plastics with Polyvinyl Chloride in a Thermogravimetric Analyzer," Albrecht Heinzl, Tim C. Keener and Soon-Jai Khang, *Archives of Environmental Protection*, Vol. 27, No. 3, pp. 11-33, 2001.

"Long-Term Evaluation of an Industrial Scale Biofilter for Odor Control at a Large Metropolitan Wastewater Treatment Plant," Lian Zhuang, Tim C. Keener, and Kaniz F. Siddiqui, *Environmental Progress*, Vol. 20, No. 4, pg. 212-218, 2001.

"Sludge Digestion Enhancement and Nutrient Removal from Anaerobic Supernatant by  $\text{Mg}(\text{OH})_2$

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Application", Wu, Q., Bishop, P.L., Keener, T.C., Stallard, J. and Stile, L., *Water Science and Technology*, Vol. 44, No.1, pp. 161-166, 2001.

"The Effects of Pulsed Corona Discharge on SO<sub>2</sub> Absorption into Water," Joo-Youp Lee, Soon-Jai Khang, Chao-Heng Tseng, and Tim C. Keener, *Industrial & Engineering Chemistry Research*, Vol 40, No. 24, pg. 5822-5830, 2001.

"Compositional Factors Affecting NO<sub>x</sub> Emissions From Ohio Coals," Kyung Sook Jung, Tim C. Keener, and Soon-Jai Khang, *Fuel Processing Technology*, Vol. 74, No. 1, pg. 49-61, 2001.

"A Technical and Economic Comparison of Biofiltration and Wet Chemical Oxidation (Scrubbing) for Odor Control at Wastewater Treatment Plants," Li Gao, Tim C. Keener, Lian Zhuang, and Kaniz F. Siddiqui, *Environmental Engineering and Policy*, Vol 2, No. 4, pg. 203-212, 2001.

"The Enhanced Effect of *In Situ* Generated Ammonia-Sulfur Aerosols on the Removal of NO<sub>x</sub> From Simulated Flue Gas," Chao-Heng Tseng, Tim C. Keener, Joo-Youp Lee, and Soon-Jai Khang, *Environmental Science and Technology*, Vol. 35, pg. 3219-3224, 2001.

"The Effect of Coal Volatility on Mercury Removal from Bituminous Coal During Mild Pyrolysis," Min Wang, Tim C. Keener, and Soon-Jai Khang, *Fuel Processing Technology*, Vol. 67, pg.147-161, 2000.

"CO<sub>2</sub> Reaction with Ca(OH)<sub>2</sub> During SO<sub>2</sub> Removal with Convective Pass Sorbent Injection and High Temperature Filtration," G. Li, Tim C. Keener, Antoinette W. Stein and Soon J. Khang, *Environmental Engineering and Policy*, Vol 2, No. 1, pg. 47-56, 2000.

"Nitrogen Oxides Removal by Pulsed Corona Enhanced Wet Electrostatic Precipitation with Ammonia and Ozone Injection: The Role of Ammonia-Sulfur Aerosols on NO<sub>x</sub> Removal," C.H. Tseng, T.C. Keener, S.J. Khang and J.Y. Lee, *Developments in Chemical Engineering and Mineral Processing*, Vol. 8, No. 5/6, pg. 483-503, 2000.

"Exposure and Health Risks Potentially Posed to Petroleum Storage Tank Cleaners by Volatile Organic Compounds," T.C. Keener, R.K. Jain, R.C. Michaels and J.W. Weber, *Environmental Engineering and Policy*, Vol. 1, No. 4, pg. 235-248, 1999.

"Sulfur Dioxide Removal by Pulsed Corona Enhanced Wet Electrostatic Precipitation," C.H. Tseng, T.C. Keener, S.J. Khang and J.Y. Lee, *Advances in Environmental Research*, 3 (3), pg. 309-325, 1999.

"Continuous Sorbent Reactions in a High Temperature Fabric Filter Following Convective Pass Ca(OH)<sub>2</sub> Injection for SO<sub>2</sub> Removal," Guang G. Li, Tim C. Keener and Antoinette W. Stein, *Journal of Air & Waste Management Association*, 49, pg. 1292-1303, 1999.

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"Aeration Recirculation in Air and High Purity Oxygen Systems for Control of VOC Emissions from Wastewater Aeration Basins," H. Zhu, T.C. Keener, P.L. Bishop, T.L. Orton, M. Wang, and K.F. Siddiqui, *Environmental Progress*, Vol. 18, No. 2, pg. 101-106, 1999.

"Temporal and Longitudinal Characteristics of Volatile Organic Compound Emissions from Aeration Units of Publicly Owned Treatment Works," H. Zhu, T.C. Keener, P.L. Bishop, T.L. Orton, M. Wang and K. Siddiqui, *Journal of the Air & Waste Management Association*, 49, pg. 434 - 443, 1999.

"The Dissolution Rate of  $\text{Ca}(\text{OH})_2$  in Aqueous Solutions," J. Wang, T. C. Keener, G. Li and S. J. Khang, *Chem. Eng. Comm.*, vol. 169, pg. 167-184, 1998.

"Investigation of the Fate of Mercury in Bituminous Coals During Mild Pyrolysis," A. Merdes, T.C. Keener, S.J. Khang, and R. G. Jenkins, *Fuel*, vol. 77, no. 15, pg. 1783-1792, 1998.

"The Emissions of Hazardous Air Pollutants from Aeration Tanks," H. Zhu, T.C. Keener, P.L. Bishop, T.L. Orton, M. Wang, and K.F. Siddiqui, *Environmental Progress*, vol 17, no. 3, pg. 148-153, 1998.

"A Calcination and Sulfation Reaction Model for Calcium Carbonate with Sulfur Dioxide," S.U. Keener, S.J. Khang, and T.C. Keener, *Advances in Environmental Research*, vol 2, no. 3, pg. 251-268, 1998.

"A Two-Stage Reactor for Studying Sorbent Reactivities in Flue Gas Desulfurization Systems Utilizing Fabric Filter Collectors," G. Li, T.C. Keener, and J. Wang, *Environmental Technology*, vol 19, pg. 475-482, 1998.

"Coal Desulfurization by Mild Pyrolysis in a Dual-Auger Coal Feeder," L. Lin, S.J. Khang and T.C. Keener, *Fuel Processing Technology*, 53, pg. 15-30, 1998.

"The Effectiveness of Aeration Recirculation in Controlling VOC Emissions from Publicly Owned Treatment Works," H. Zhu, H., T.C. Keener, T.L. Orton, P.L. Bishop, S.J. Khang, and K. Siddiqui, *Journal of Air & Waste Management Association*, 47, pg. 1259-1267, 1997.

"Attrition and Changes in Size Distribution of Lime Sorbents in a Circulating Fluidized Bed Absorber," J.L. Cook, S.J. Khang, S.K. Lee and T.C. Keener, *Powder Technology*, 89, pg. 1-8, 1996.

"The Effect of Hygroscopic Additives on  $\text{Ca}(\text{OH})_2$  Utilization in Spray Dryer Flue Gas Desulfurization," J. Wang and T.C. Keener, *Environmental Technology*, 17, pg. 1047-1057, 1996.

"Catalytic Production of Elemental Sulfur from the Thermal Decomposition of  $\text{H}_2\text{S}$  in the Presence

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of CO<sub>2</sub>," D. Soriano, T.C. Keener and S.J. Khang, *Chem. Eng. Comm.*, **143**, pg. 73-89, 1996.

"The Use of a Circulating Fluidized Bed Absorber for the Control Of Sulfur Dioxide Emissions by Calcium Oxide Sorbent via *In-Situ* Hydration," M.X. Jiang, T.C. Keener and S.J. Khang, *Powder Technology*, **85**, pg. 115-126, 1995.

"Heated Fly Ash/Hydrated Lime Slurries for SO<sub>2</sub> Removal in Spray Dryer Absorbers," J. Sanders, T.C. Keener and J. Wang, *Industrial & Engineering Chemistry Research*, **34**, pg. 302-307, 1995.

"SO<sub>2</sub> Removal by NH<sub>3</sub> Gas Injection: Effects of Temperature and Moisture Content," H. Bai, P. Biswas and T.C. Keener, *Industrial & Engineering Chemistry Research*, **33**, pg. 1231-1236, 1994.

"Attrition of Lime Sorbents During Fluidization in a Circulating Fluidized Bed Absorber," S. K. Lee, T. C. Keener and S. J. Khang, *Industrial & Engineering Chemistry Research*, **32**, pg. 2758-2763, 1993.

"A Qualitative Analysis of the Effects of Water Vapor on Multi-Component Vapor Phase Carbon Adsorption," R. Gong and T. C. Keener, *Journal of the Air and Waste Management Association*, **43**, pg. 864-872, 1993.

"Kinetics of the Sodium Bicarbonate-Sulfur Dioxide Reaction," T.C. Keener and S.J. Khang, *Chemical Engineering Science*, **48**, pg. 2859-2865, 1993.

"Denitrification of Coal by Mild Pyrolysis in a Novel Coal Feeder," Thih-Liang Yeh, T.C. Keener, S.J. Khang and R.G. Jenkins, *Fuel Processing Technology*, **33**, pg. 33-48, 1993.

"Thermal Decomposition of Limestone in a Large Scale Thermogravimetric Analyzer," J.T. Lee, T.C. Keener, M. Knoderer and S.J. Khang, *Thermochimica Acta*, **213**, pg. 223-240, 1993.

"Effects of Leaching on Pore Size Distribution of Solidified/Stabilized Wastes," R. Gong, P. Bishop and T.C. Keener, *Journal of Hazardous Materials*, **31**, pg. 59-74, 1992.

"Chemical Fixation of Flue Gas Desulfurization Sludges and Fly Ash," P.L. Bishop, T.C. Keener, D.C. Dusing, and R. Gong, *Stabilization and Solidification of Hazardous, Radioactive and Mixed Wastes, ASTM, STP 1123*, pg. 103-118, 1992.

"Effect of REDOX Potential on Leaching From Stabilized/Solidified Waste Materials," D.C. Dusing, P.L. Bishop and T.C. Keener, *Journal of the Air and Waste Management Association*, **42**, pg. 56-62, 1992.

"Particle Formation by NH<sub>3</sub>-SO<sub>2</sub> Reactions at Trace Water Conditions," H. Bai, P. Biswas and T.C. Keener, *Industrial and Engineering Chemistry Research*, **31**, pg. 88-94, 1992.

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"Chemical Fixation of Coal Power Plant Wastes," D. Dusing, P. Bishop, R. Gong and T.C. Keener, *Hazardous and Industrial Materials*, Technomic Publishing Co., Lancaster, PA, 385-397, 1991.

"A Combined  $\text{Ca}(\text{OH})_2/\text{NH}_3$  Flue Gas Desulfurization Process for High Sulfur Coal," A. Pakrasi, W.T. Davis, G.D. Reed and T.C. Keener, *Journal of the Air and Waste Management Association*, **40**, pg. 987-992, 1990.

"Prediction of Activated Carbon Performance Under High Relative Humidity Conditions," T.C. Keener and D. Zhou, *Environmental Progress*, **9**, pg. 40-46, 1990.

"A Dry Scrubbing Model For  $\text{SO}_2$  Removal Using A Simplified Reaction Rate Expression," T.C. Keener and P. Biswas, *Chemical Engineering Communications*, **81**, pg. 97-108, 1989.

"Surface Area Development of Calcium Based Materials Undergoing Thermal Decomposition at Intermediate Temperatures," T.C. Keener and Xiaolin Jiang, *Chemical Engineering Communications*, **75**, pg. 1-22, 1989.

"The Application of a Mobile Solvent Recovery Process to Minimize Hazardous Waste," T.C. Keener, *Hazardous and Industrial Solid Waste Minimization Practices*, *ASTM Publication STP 1043*, Edited by Conway et al., 1989.

"Thermal Decomposition of Sodium Bicarbonate," T.C. Keener, G.C. Frazier and W.T. Davis, *Chemical Engineering Communications*, **33**, pg. 93-105, 1985.

"Study of the Reaction of  $\text{SO}_2$  with  $\text{NaHCO}_3$  and  $\text{Na}_2\text{CO}_3$ ," T.C. Keener and W.T. Davis, *Journal of the Air Pollution Control Association*, **334**, pg. 651-654, 1984.

### *Conference Proceedings*

"The ACCEND Program: A Combined BS and MS Program in Environmental Engineering That Includes Co-operative Work Experience," Bishop, P.L., Keener, T.C. Kukreti, A.R. and Kowel, S.T., *Proceedings, 2<sup>nd</sup> International Seminar on Environmental Engineering Education*, Zurich, Switzerland, September 24-26, 2003.

"The Impact Of Gasoline Additives On Air Quality In Developing Countries," H. Bravo A., Tim C. Keener, Mingming Lu, P. Sanchez A., R. Sosa E., *Proceedings of the 8<sup>th</sup> International Conference on Atmospheric Sciences and Applications to Air Quality (ASAAQ)*, Tsukuba International Congress Center, Tsukuba Science City, Japan, March 11-13, 2003.

" $\text{CO}_2$  Separation from Power Plant Flue Gases with Reclaimed  $\text{Mg}(\text{OH})_2$ ," Kyung S. Jung, Tim C. Keener, Soon J. Khang, Sang K. Lee, *Proceedings of Ohio Air Pollution Research Symposium*, paper OS-02-03, Toledo, Ohio, October 25, 2002.

"Circulating Aeration System for Controlling VOC Emissions From Aeration Basins in POTWs," Kun Zhao, Keener, T. C., Sundrup, J., *Proceedings of the 95th Annual Meeting & Exhibition of the Air & Waste Management Association*, paper 42529, Baltimore, Maryland, USA, June 23-27, 2002.

"Feasibility of CO<sub>2</sub> Separation from Power Plant Flue Gases with Reclaimed Mg(OH)<sub>2</sub>," Kyung Sook Jung, Keener, T.C., and Khang, S.J., *Proceedings of the 95th Annual Meeting & Exhibition of the Air & Waste Management Association*, paper 43122, Baltimore, Maryland, USA, June 23-27, 2002.

"Biological Phosphate Uptake and Release: Effect of pH and Mg<sup>2+</sup>", Wu, Q., Bishop, P.L. and Keener, T.C., *Proceedings, WEF Special Conference on Plant Operations and Maintenance of Small & Medium Wastewater Treatment Plants*, Cincinnati, Ohio, USA, September 16-18, 2001.

"A New Strategy to Reduce the Risk of Struvite Deposition in Municipal Wastewater Treatment Plants", Wu, Q., Bishop, P.L. and Keener, T.C., *Proceedings, WEF Special Conference on Plant Operations and Maintenance of Small & Medium Wastewater Treatment Plants*, Cincinnati, Ohio, USA, September 16-18, 2001.

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## Reports

A complete list of reports is available on request.

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